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Prebiotics, gut microbiota and metabolic risks: Unveiling the relationship

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ABSTRACT

The human gastrointestinal tract is colonized by trillions of microbes comprising thousands of bacterial phylotypes. Recent metagenomic studies of the human gut microbiota have revealed the presence of millions of genes, as compared to genes present in the entire human body. Perturbation in the level of gut microorganisms may lead to the onset of metabolic disorders. However, compelling evidence has also suggested that a particular gut microbial community may halt the occurrence of metabolic risk factors. Restoration of the beneficial gut microbial balance is difficult to achieve but the exploitation of prebiotics has led to promising outcomes in various studies.

Contents

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1. Introduction

Prebiotics are non-digestible food components that selectively stimulate the growth or activity of specific indigenous bacteria in the digestive tract in a manner claimed to be beneficial for the host. They were identified in the early 1950s by Gyorgy (1953) as "bifidus factor," a bifidogenic substance that selectively improved the growth of *bifidobacteria*. The term prebiotic was first devised in 1995 by Gibson and co-workers (Gibson & Roberfroid, 1995; Sharma, Agarwal, & Verma, 2012). Earlier work on prebiotics only elaborated on the microbial changes in the human digestive ecosystem. Later work provided evidence that prebiotics allow desirable changes in the composition as well as the activity of the gastrointestinal microflora and confer health benefits to the host (Kanakupt, Boler, Dunsford, & Fahey, 2011; Nagpal, Yadav, & Marotta, 2014).

Prebiotics are primarily carbohydrates (oligosaccharides and polysaccharides), but may include some non-carbohydrate moieties. Soluble fibres are the most prevailing type of prebiotics. Nevertheless, various other forms of dietary fibre may serve the purpose. In this context, criteria have been established to categorize any food ingredient as a candidate prebiotics: they have the ability to resist gastric hydrolysis by digestive enzymes and remain unabsorbed in the upper gastrointestinal tract; they undergo fermentation by resident microbiota in the large intestine; and they stimulate the activity/growth of potentially beneficial intestinal bacteria (Xiao, Fei, & Pang, 2014; Yeo, Ooi, Lim, & Liong, 2009).

Mechanistically, prebiotics are non-viable food constituents having pronounced effect on human health by modulating colonic microflora (FAO, 2007). They induce specific changes in the composition of gut microbiota, increase the number of *bifidobacteria* and *lactobacilli*. Alongside, prebiotics decrease the toxin-producing bacteria like bacteroides, proteolytic clostridia and *Escherichia coli* (Ogueke, Owuamanam, Ihediohanma, & Iwouno, 2010). According to the criteria, many non-digestible food oligosaccharides exhibit prebiotic activities. Likewise, fructooligosaccharides, xylooligosaccharides, isomaltooligosaccharides and glucooligosaccharides as well as some sugar alcohols and polysaccharides (modified and resistant starch) are also included in this category. They can either be produced enzymatically or found naturally in some plants (Cummings, Macfarlane, & Englyst, 2001).

The promising health benefits associated with prebiotics are improvement in the gastrointestinal microflora, enhanced mineral absorption, stimulation of the immune system, reduced risk of irritable bowel syndrome and of constipation (Gibson, Probert, van Loo, Rastall, & Roberfroid, 2004). They also prevent colorectal cancer and exhibit cholesterol lowering potential (Kelly, 2003). Nevertheless, the health enhancing effects of prebiotics are not direct as they selectively nourish the microbial community *i.e. lactobacilli* and *bifidobacteria* that in turn improve gut health. Approximately 300 to 500 species of bacteria occur in the human gastrointestinal tract that becomes denser in the large intestine, approaching a concentration of microbial cells 10^{11}/g of luminal content (Guarner & Malagelada, 2003). It has been established that almost 55% of faecal bulk consists of microorganisms. The microbial colonization in the digestive tract is markedly influenced by transit time and luminal pH (Paineau et al., 2008).

The majority of colon bacteria are anaerobes that avail energy through fermentation. In this context, main fermentative substrates from dietary source are non-digestible carbohydrates *i.e.* oligosaccharides, fibres, resistant starches and non-starch polysaccharides that escape digestion in the small intestine. Nonetheless, carbohydrate fermentation products are effective substrates leading to gradient utilization by the colon (Macfarlane, Steed, & Macfarlane, 2008). The ascending colon can break down the sugars and the mass of incoming carbohydrates is being fermented to short chain fatty acids (SCFAs), mainly acetate, propionate and butyrate. Besides, other metabolites like pyruvate, lactate, succinate and ethanol as well as gases H_2, CO_2, H_2S and CH_4 are produced (Whelan, Judd, & Preedy, 2005).

SCFAs are captured by the colonic mucosa and contribute towards energy needs of the host. Acetate is primarily metabolized in the kidney, heart, brain and human muscles, whilst propionate, a glucogenic precursor, suppresses cholesterol production. Butyrate is utilized by the colonic epithelium where it helps in cell growth regulation and differentiation (Sangwan, Tomar, Singh, Singh, & Ali, 2011).

Prebiotics exhibit imperative technological properties as well as attractive nutritional value. In food formulations, they appreciably upgrade sensory features and improve taste and mouth feel. In order to become part of functional food, prebiotics must be stable to processing conditions like heat, pH and Maillard reaction because degraded mono- and disaccharides are not available for bacterial fermentation. Previous investigations on prebiotics have shown that heating at low pH causes reduction in prebiotic activity whilst other conditions did not alter stability (Al-Sheraji et al., 2013; Bohm, Kaiser, Trebstein, & Henle, 2006).

Inclusion of prebiotics in food is a natural way to provide healthy ingredients to the consumers. Most of the prebiotics are easily consumable and give desired functionality to the food items (Courtin, Swennen, Verjans, & Delcour, 2009). For instance, short chain prebiotics act like sugars and contribute to crispiness and browning of the end product. Long chain prebiotics work as fat replacer, escalate the texture and mouthfeel. The majority of the prebiotics are not considerably distorted or damaged by processing treatments, thus retaining their functionality throughout the alimentary tract. Contrarily, most of the probiotics in the finished products have been killed due to harsh processing conditions that are required to eradicate microbes for food safety reasons (Bohm et al., 2006).

2. Prebiotics and metabolic syndromes

Recent advances to curtail disease progression have opened new avenues for the development of prebiotic-based dietary interventions to halt the incidence of metabolic dysfunction (Riccioni et al., 2012). In the present scenario, production of designer foods with natural ingredients like prebiotics is a pragmatic approach. A number of epidemiological studies have illuminated the cardioprotective effect of diets high in